

Opera's neutrinos and the Robertson test theory of the Lorentz transformations*

Jose G. Vargas[†]

Abstract

The difference in light's travel time from CERN to GPS to Gran Sasso, on the one hand, and light going the direct route in vacuum (mimicked by neutrinos), on the other hand, is analyzed with a modified Robertson test theory of the Lorentz transformations. The modification consists simply in removing the restriction of what Robertson referred to as agreement to equate the to and from speeds of light. For reasons that will be contained in a paper to soon follow, we restrict ourselves, within the new freedom, to the case of preferred frame kinematics with absolute simultaneity.

At the level of not assuming any concomitant dynamical changes in this alternative, the analysis yields *zero effect*, i.e. no change with respect to special relativity (to be expected). The 60 ns would thus remain unexplained. However, a gravitation related effect that would likely accompany an alternative kinematics yields that value up to uncertainties due to the need to simplify the experimental set up for analysis. The effect amounts to $(\lambda/2)(D/c)(V/c)^2$, where D is distance to GPS, V is speed with respect to the frame of isotropy of the cosmic background radiation and λ is a factor greater than 1, but likely not greater than 1.2 or 1.3, that reflects lack of precise knowledge of the average distance to the common view GPS satellite. A λ factor of 1.2 yields 60 ns.

*To Dr. Douglas G. Torr, supporter and collaborator of several decades. Doug and I have always shared one essential belief—that there is a deeper reality behind or beyond special relativity.

[†]138 Promontory Rd., Columbia, SC 29209.

1 Introduction

In their analysis [1], the Opera group assumed the constancy of the one-way speed of light, assumption shared by the physics community at large. But most physicists and philosophers interested in the foundations of SR assert that synchronizations and the one-way speed of light are matters of convention covered under the umbrella of Reichenbach's thesis of conventionality of synchronizations [2]. Consistently with this, they maintain that certain transformations alternative to the ones by Lorentz, like the para-Lorentzian transformations that we shall later consider, do not actually represent a new physics. High energy physicists, to name only the most obvious case, would find such a statement difficult to digest (This author was caught in the defense of his Ph. D. dissertation between a conventionalist and a high energy physicist; yes, I published and got my degree!). Those observations and my little anecdote are meant to ask for patience by skeptic readers, since the issue is a very subtle one. See in this respect Chapter 8 of Bohm's book on the special theory of relativity [3]

Central to our discussion will be the realization that the present version of the principle of equivalence is by itself enough to imply the Lorentz transformations (LTs) without any such conventions [4] and, therefore, imply a constant one-way speed that is not conventional (See there references also to previous related works, starting as early as in 1910). There is no way out of this under present interpretations of the relativity principle.

If the one-way speed of light were a matter of convention, the implications of the now famous 60 *ns* should not be a cause for concern. A convention (a definition for Einstein; an agreement for H. P. Robertson) cannot have foundation-shaking consequences. How would neutrinos know what convention was used to determine when they should arrive in Gran Sasso? However, there is some sense in which one could speak of convention, though it is dangerous to do so. I shall explain by advancing the contents of section 5.

If light traveled with a direction dependent speed different from c from CERN to GPS satellites and from there to Gran Sasso, so would the speed of light in a tunnel (vacuum having made in it) between CERN and Gran Sasso. Under present understanding that we do not reject, neutrinos would also travel with a speed slightly smaller but virtually equal to the speed of light in vacuum. That speed would thus be, like light's under the thesis of this paper, direction dependent. So, this measurement amounts in principle to sending light between two places through a direct and indirect route. Any

changes in the arrival time of light from CERN to Gran Sasso via GPS would be compensated exactly by the change in the arrival time of light going the direct route in a straight tunnel. On the basis of results like this, some may find it justifiable to make the assumption of equality of the to and fro speeds since there is no way to tell the difference if it were not so.

The alternative to be considered here is one with preferred frame that we shall call para-Lorentzian (PL), an alternative that nameless or under a different names, has been invoked by different researchers for various purposes. It would be premature to give here acknowledgements mainly because of the lengthy and negative comments that would have to be made in more than one case. Future Opera-like experiments will tell whether the subject is worth revisiting and whether it pertains to give credits and discredits.

The key part of this paper is sections 5 to 7. In section 5, we perform a para-Lorentzian analysis of the Opera experiment under the trite assumption that one should only look at the kinematics. It does not explain why neutrinos show up as early as they do.

In section 6. we imagine what gravitation could be like in a non-relativistic world that looks relativistic as per the preceding section, but where we let Newton's law be directly related to the preferred frame, rather than to the rest frame of the mass creating the gravitational field. In other words, we are speaking of a potential gravitational concomitant of a physics on the PL scenario.

In section 7, we compute the time of arrival of neutrinos in the context of that concomitant. It agrees so closely with the 60 *ns* that luck must be at work given the simplification of the experiment made to be able to perform the analysis with available data and resources.

The rationale behind the contents of sections 6 and 7 will not be easily understood without a paper which should soon follow [5]. It was written a year ago as an outgrowth of a talk given a year ago at Bauman University in Moscow. It makes the case for proptime as a fifth dimension. The argument is based on superseding the foundations of present day differential geometry. A new perspective emerges on issues such as the equivalence principle. In section 8, the last one, we shall give a preview of the implications of the 5-D scenario presented in that preprint [5]. Just to provide some limited perspective for the present paper, let us just say the following. The LTs would then be just the facade of a more complex reality consistent with absolute simultaneity and containing a preferred frame in its fold; physics will continue to look relativistic and one will continue to study it even if the

physics presented in this paper were correct and accepted. But there may be the occasional exception under uncommon circumstances, Opera possibly being a case in point.

We complete the description of the contents of the paper. In section 2, we show contradiction between a statement by Einstein about the one-way speed of light and what his first postulate for SR implies. This contradiction could not have been noted at the time. In section 3, we revise the Robertson test theory of the Lorentz transformations [6] by removing from it the equality of the two and fro speeds of light. In section 4, we deal with the PL transformations. All that is necessary, or at least very relevant, for the sections that then follow, whose contents has already been described.

2 Einstein on the one-way speed of light

The opinion of Einstein is relevant here in the following context. We shall not assume in this paper that the one way speed of light is a constant, but only that the two-way speed is .If, for whatever reason, we set the one-way speed to be equal to the two-way speed, the constancy of the latter implies the constancy of the former. In this regard, Einstein in 1905 incurred in a contradiction that could not be ascertained at the time, and that he felt might be possible: “... We assume that this definition of synchronism is free from contradictions ...” [7]

The contradiction is stated using this and the next two paragraphs. Einstein postulated the equivalence of all the inertial frames in spacetime. It was not realized at the time that this suffices to obtain the LTs up to the value of a constant, if negative, [4] and references therein. This implies that the square root of the negative inverse of that constant is an invariant with dimension of velocity. This invariant is the only speed which remains constant under those transformations. Under that postulate, the one-way speed of light is not a matter of conventions, but to be determined by experiment. The only reasonable option for that constant is the speed of light. The only way out of this consequence of invariant one-way speed would consist in not assuming the equivalence of all the inertial frames in the usual sense, the only sense presently available.

The issue of synchronizations and of the constant speed of light are intertwined. In paragraphs preceding immediately the aforementioned citation, Einstein had stated: “We have not defined a common “time” for A and B, for

the latter cannot be defined at all unless we establish *by definition* that the “time” required by light to travel from A to B equals the “time” it requires to travel from B to A ...” Markings and emphasis are as in the original. We wish to call attention to the “*by definition*”.

Einstein defines times t_A , t_B and t'_A instrumental in stating the equality of the two and for speeds of light as follows: “In accordance with definition the two clocks synchronize if $t_B - t_A = t'_A - t_B$ ” A definition is a convention. We cannot make Planck’s constant be whatever we want it to be as a matter of definition. But Einstein did that with the one-way speed of light, even though his postulate of equivalence implied that it is not a matter of definition. End of explanation of contradiction.

Up to this point in this paper, the one way of speed of light has emerged as being a direct consequence of a *convention* [2], a *theorem* [4], and a *definition* [7]. The issue then becomes what does the available experimental evidence say about all this. Robertson wrote a most significance paper about this titled “Postulate *versus* observation in the Special Theory of Relativity” (emphasis in original). In the process of understanding its essence, we shall again find the characterization of the one-way speed of light. We need to understand the essence of the paper.

3 Revision of Robertson’s test theory of the Lorentz transformations

Robertson postulated [6]

(a) the existence of “a reference frame Σ —Einstein’s “rest system”—in which light is propagated rectilinearly and isotropically in free space with constant speed c ” (Emphasis in original).

He assumed for his purpose

(b) that we may “... confine ourselves to the consideration of events E in a space-time neighborhood of a given event E_0 which is so small that we may linearize T ,...” T is the general transformation that constitutes his starting point.

He then went to

(c) “... *adopt the procedure* proposed by Einstein for setting clocks which are carried by observers R at various points x^a in the reference frame S ” (emphasis added). Robertson had previously introduced S as Einstein’s

moving system.

In connection with synchronizing clocks at a distance through reflection of a light signal and dividing by two the time of the two way trip, Robertson writes:

(d) “We *agree* to set the auxiliary clock ... in such a way that it records the time t_0 for the event E of reflection”.

Further down the text, he goes on to say

(e) “... Einstein’s synchronization insures *as a matter of definition* the equality of the forward and backward velocity along any given line in S , ...” Emphasis in original

He interprets the null result of the Michelson-Morley (MM) experiment as meaning:

(f) “*The total time required by light to traverse in free space, a distance l and to return is independent of direction*”. Emphasis in original.

He proceeds similarly with the experiment of Kennedy-Thorndike (KT):

(g) “*The total time required by light to traverse a closed path in S is independent of the velocity v of S with respect to Σ* ”. Emphasis in original.

And finally, for the Ives-Stilwell experiment (IS):

(h) “*The frequency of a moving atomic source is altered by the factor $(1 - u^2/c^2)^{1/2}$, where u is the velocity of the source with respect to the observer.*” Emphasis in original.

In that way, Robertson reaches the standard metric of special relativity. As is well known, it is left invariant by translations, LTs, spatial rotations and products of those.

If one gives a value to the one way speed of light in the path from CERN (C) to GPS (S) to Gran Sasso (G), one should ignore (c), (d) and (e) and treat Opera as a fourth experiment —though highly imperfect because of its many complications— for a the revised Robertson test theory of the LTs. To be precise, the analysis will induce us into some back engineering that it takes us beyond the testing of the LTs. We are led into considering the issue of whether we can consider an alternative to the LTs in a purely kinematical context. If one considers a plausible concomitant change in Newton’s law at the level of one part in 10^6 in the earth, Opera’s non-null result might be a way in which nature might be voicing lack of conformity with (c).

In discussing the transformations that we are about to consider in the next section, Thirring [8] stated “... it would be possible to save the notion of absolute simultaneity, but no one is willing to make the necessary *sacrifices any more*: philosophical principles are not as persuasive as *mathematical*

elegance” (emphasis added).

To the key terms *convention*, *theorem* and *definition* we add the also key terms *adoption of a procedure*, *agreement*, *sacrifices any more*, and *mathematical elegance*.

In the present paper, the one-way speed of light is a theorem if one assumes the only version of the equivalence principle that appears to be possible in a pure spacetime context. In the remainder of this paper, we shall present a new context, to be further developed in the announced sequence [5], more concerned with mathematical elegance.

4 Para-Lorentzian transformations

The revision of the Robertson test theory is better performed in terms of coordinate transformations, provided they represent changes of frames and not just simply changes of markers. We shall be more specific about this in the next section.

Of all the members of the family of transformations that comply with (f), (g) and (h) but not (e), we are now choosing the specific member where time is absolute. This is not only for esthetic or simplicity reasons, but because PL is the only member of the family chosen by our theoretical considerations on the arena of physics [5]. These transformations have been considered by a few others in the past, contributions not worth mentioning at this point because of necessary negative comments that should accompany due credit of perhaps the other wise most important one. But, if these transformations prove their worth, their work should revisited.

Let \mathbf{V} of components $(v, 0, 0)$ with respect to some appropriately oriented reference frame $S'(t', x', y', z')$ be the velocity of the laboratory system with respect to the preferred frame $\Sigma(T, X, Y, Z)$. With the Robertson approach but with the specified changes, one can easily show how to mathematically represent a hypothetical non-compliance of nature with any one or several of (e), (f), (g) and (h) [9]. The family of “transformations” that replaces the LTs if (d) is not satisfied is

$$x' = \gamma \cdot (X - VT), \quad y' = Y, \quad z' = Z, \quad t' = hX + (\gamma^{-1} - hV)T, \quad (1)$$

where h is a family of functions of V . These transformations contain both the LTs and the PL transformations, the last ones being

$$x' = \gamma \cdot (X - VT), \quad y' = Y, \quad z' = Z, \quad t' = \gamma^{-1}T. \quad (2)$$

We define unprimed low case quantities by

$$x = x', \quad y = y', \quad z = z', \quad t = t' - Vx' \quad (3)$$

and use (3) in (2). We thus identify $S(t, x, y, z)$ as a relativistic frame with the same velocity as the PL frame S'

$$x = \gamma \cdot (X - VT), \quad y = Y, \quad z = Z, \quad t = \gamma(T - Vx). \quad (4)$$

For arbitrary direction of the velocity, the relation between S and S' ,

$$\mathbf{r} = \mathbf{r}', \quad t = t' - (\mathbf{V} \cdot \mathbf{r}). \quad (5)$$

allows us to compute more easily than resorting directly to Σ .

All these coordinate transformations are to be viewed not as changes of markers but as representative of changes of frames. In affine space, the equation

$$x^\mu \mathbf{e}_\mu = x'^\mu \mathbf{e}'_\mu, \quad (6)$$

expresses that the translation vector can be expressed in terms of just any vector basis. A change of coordinates thus induces a change of basis and vice versa. But alternative coordinates can also be viewed simply as different sets of markers, a comment that applies in particular to changes between Lorentz frames and frames for kinematics that do not comply with any one or several of (d), (e), (g) and (e). This has an important consequence. One is not going to find any effects in experiment where there is not some element that distinguishes a change of basis from a change of markers, as the computations would be the same in both cases. Since no effect can arise from a change of markers, no effect would be found by identical computations for the change of frames.

Returning to our PL world, let \mathbf{c} and \mathbf{c}' be the velocity of light relative to S and S' . We have

$$\mathbf{c}' = \frac{d\mathbf{r}'}{dt'} = \frac{d\mathbf{r}'}{dt} \frac{dt}{dt'} = \frac{d\mathbf{r}}{dt} \frac{dt}{dt'} = \mathbf{c}(1 - \mathbf{V} \cdot \mathbf{c}'), \quad (7)$$

where we have used (4). Since \mathbf{c} and \mathbf{c}' are colinear, their unit vectors are equal

$$\mathbf{c} = \mathbf{n} = \mathbf{n}'. \quad (8)$$

where $c' \equiv |\mathbf{c}'|$ and where we take c as unit of speed. For $V \ll 1$, we get from (7),

$$\frac{1}{c'} = 1 + \mathbf{V} \cdot \mathbf{c}' + (\mathbf{V} \cdot \mathbf{c}')^2 + \dots \quad (9)$$

We also have

$$\mathbf{c} = \frac{d\mathbf{r}}{dt'} \frac{dt'}{dt} = \mathbf{c}'(1 + \mathbf{V} \cdot \mathbf{c}), \quad (10)$$

and

$$\frac{1}{c'} = 1 + \mathbf{V} \cdot \mathbf{c} = 1 + \mathbf{V} \cdot \mathbf{n} = 1 + \mathbf{V} \cdot \mathbf{n}', \quad (11)$$

which are exact equations.

5 Para-Lorentzian analysis of the Opera measurement

We shall now proceed to present an analysis of the problem of measurement of the one way speed of light tailored made to the Opera experiment. This is a refinement and generalization of a similar argument Bohm made in just one dimension [3].

In S' let the positions vectors from C to S, from S to G and from C to G will be denoted as \mathbf{D}_C , \mathbf{D}_G and \mathbf{d} . The respective unit vectors will be named as \mathbf{n}'_C , \mathbf{n}'_G and \mathbf{n}'_ν . And we shall use the symbols c'_C , c'_G and c'_ν to refer to the speed of light corresponding to those directions. Obviously

$$\mathbf{D}_C + \mathbf{D}_G - \mathbf{d} = \mathbf{0}. \quad (12)$$

We shall now show that light satisfying equations (7) to (11) take the same time to cover the closed path CSGC (using a hypothetical tunnel between C and G) as if light were travelling always at constant speed c . This time is given by

$$\frac{D_C}{c'_C} + \frac{D_G}{c'_G} + \frac{d}{c'_{-\nu}} = 0, \quad (13)$$

where $c'_{-\nu}$ represents the speed of light if it were going from G to C.

Using (11), expression (13) becomes

$$\frac{D_C}{c}(1 + \mathbf{V} \cdot \mathbf{n}'_C) + \frac{D_G}{c}(1 + \mathbf{V} \cdot \mathbf{n}'_G) + \frac{d}{c}(1 - \mathbf{V} \cdot \mathbf{n}'_\nu) = 0, \quad (14)$$

where we have made c explicit outside the parenthesis to make obvious that we are adding time intervals. The sum of the terms obtained from the units in the parentheses yields the time that light would take to cover the path

with speed c . The other terms yield the dot product by \mathbf{V} of the left hand side of (12), and is thus null. The point of null effect has been made.

Notice that the result just obtained is exact and, therefore, independent of how large c' could become. And it is because cancellations like this are the norm rather than the exception that one should not be concerned about an underlying reality that were not relativistic; it might still appear to be so.

We proceed to develop another important observation in order to understand where we should look or not look for 60 ns in the present context. Let t and t' be the times taken by light to cover the trajectories indicated by subscripts. We have proved that

$$t'_{CSG} + t'_{GSC} = t_{CSG} + t_{GSC}, \quad (15)$$

and similarly

$$t'_{CG} + t'_{GC} = t_{CG} + t_{GC}. \quad (16)$$

Solving for t'_{GC} in (16) and substituting in (15), we get

$$t_{CG} - t'_{CG} = t_{CSG} - t'_{CSG}. \quad (17)$$

t_{CG} is the time that neutrinos take to go from C to G at the speed c , and t'_{GC} is the actual time they took as per PL.

Notice that the left hand side of equation (17) does not depend on the point S. Hence neither can the right hand side even if each of its two terms does.

To conclude, if PL had to do only with the dependence of the speed of light with direction, it could not account for the effect. Many would be saying: I told you so. But there is far more to spacetime related structure than just speed of light. See, for instance, Maciel and Tiomno in connection with the concept of (practical) rigidity in SR and PL [10]. And *if there were more*, a law of nature would determine when neutrinos should arrive in Gran Sasso, not some convention that neutrinos do not know of.

6 Newton's law in preferred frame context

As explained by Maciel and Tiomno, the rotation of a practically rigid body defines two different physical configurations depending of whether we are in a SR world or a PL world. The role that practical rigidity plays in the analysis by Maciel and Tiomno of resonance experiments in centrifuges [10] is played

by Newton's law in the Opera experiment. In one case as in the other, it is a matter of the differences ab initio between physical configurations of an experiment which, against all appearances, is not the same in a world as in the other, say the worlds of SR and PL.

Equations (5) by themselves would seem to preclude any such difference, since Newton's law pertains to gravitostatics, where only displacement vectors in three dimensions should matter; these are the same in SR as in PL. Nature, however, could be more subtle. We have to imagine what such a PL world might look like.

Here is the crux of the problem. Given the peculiarities of light (as per the previous section), synchronizations that take place in actual life are Einstein's, not PL synchronizations. Consider now slow clock transport. Unless a clock is at rest in Σ , it is not moving slowly. Only if the laboratory were almost at rest in Σ would slow clock transport be a valid, approximate synchronization procedure in a *PL* world, but the reason would be that, in that frame, SR and PL physics would be practically identical. In a PL world there is an *unavoidable disconnect* between its *hypothetical relation of simultaneity* and how clocks actually behave. Because of this, SR will always be part of the physics, barring the exceptional situations that catch this "malicious nature" of guard.

Synchronizations are key to the functioning of the GPS system but, in the weak or virtually flat approximation of the preferred frame scenario, Newton's dynamical law would take its standard form in the frame Σ , not in the frame S' . That is the thesis we use here to analyze Opera. For different reasons, those systems have to be and actually are tinkered with. Add to it that Newton's constant G and the mass of the earth are known only to one part in 10^4 and we have got that, given is precision, the *GPS system is an almost miraculous feat* of scientific and technological engineering. It is monitored and corrected continuously, using the more reliable system of atomic clocks on earth. Thanks to the *stability provided through that monitoring* and the self-consistency that one so achieves between the participant satellites, one can measure small distances using the two-way speed of light.

One computes highly precise differences between the position vectors of two places without subtracting the would-be-imprecise actual distances to the center of the earth. In addition, one is dealing with distances computed with intervention of two-way speeds of light. This is not obvious because, although one-way ranging is involved in the common use of the GPS system, the basic functioning of the system involves satellites viewed in different

directions. it has the same as two-way determinations. All this goes to say that these *computed measurements amount to corrections rather than actual values*. This is like the quantum field corrections of the hydrogen atom's fine structure. Relativistic quantum mechanics provides the bulk of the value (so to speak), but not the corrections; quantum field theory on its own cannot provide the value, only the corrections. Hence it does not matter for most purposes whether we are working with a very precise value for the mass of the earth or not.

From a PL perspective, the GPS system would be a hybrid one. The foundations of its gravitational dynamics would not be in accordance with the synchronizations that actually take place. The foundations are “preferred frame based”, *but measurements with this system (say distances in the Opera experiment) are differential* and thus based on local assumptions related to the wrong synchronizations. For each neutrino event, the distance covered by light in going from CERN to GPS satellite to Gran Sasso is determined using just one satellite, in common view from both places. It is an apparent S' distance because it is computed through the use of signals from a self-consistent system but whose orbit is then computed by “wrongly using” the underlying Newton's law. It should be based on Σ distances, not on S' distances, much less on apparent S' distances.

Consequently, we proceed to compute the effect on the time of flight of light under a presumed effect of this unavoidable mismatch. We assume that the real distance in S' is not the one actually considered to have been measured in S' (through computation on the basis of the wrong assumptions), but that it is related to it like the real Σ distance is related to the the real S' distance. Thus we shall use the relation between Σ and S' for our analysis. How could one do better than this? There are three legs to the answer: theoretical, phenomenological and practical.

From a theoretical perspective, one cannot without developing at least the beginning of a theory that covers at least a new gravitation the facade of which (loosely speaking) is Einstein's theory of gravity.

From a practical perspective, a PL-consistent GPS system would be practically unworkable. Those who designed the system already know what is practical because, as explained, they developed a very precise system going beyond the precision in the knowledge of G and of the mass of the earth.

From a phenomenological/modelling perspective, a more sophisticated analysis would have to be carried out by those who designed the system and maintain it, but perhaps only for case like this, where one sees the frame

behind the facade. Such an effort is unwarranted at this point. Confirmation of the same anomaly by other experiments should take place first, specially since such additional experiments appear to be in the workings already.

Finally a word, just in case. Inconsistencies have appeared in measurements of G at a level as high as 1 part in 10^4 . The second order effect that we are about to consider would be too small in order to explain such inconsistencies. But one might not be able to totally exclude first order effects in other situations.

7 Analysis of the Opera experiment with concomitant gravitational effect

Let us assume that we follow the course of action just outlined. We rewrite Eqs. (2) as

$$X = \gamma \cdot (x' + Vt'), \quad Y = y', \quad Z' = z', \quad T = t'. \quad (18)$$

For arbitrary direction of velocity of S' , the assignment of 3-vectors to pairs of “points” (meaning C and S, or S and G, or C and G) at constant time is given by

$$\Delta \mathbf{R} = \Delta \mathbf{r}' + \mathbf{V} \frac{\gamma - 1}{V^2} (\mathbf{V} \cdot \Delta \mathbf{r}'), \quad (19)$$

directly from the spatial part of the PL transformations, the same as for the LTs. In second order

$$\Delta \mathbf{R} = \Delta \mathbf{r}' + \frac{1}{2} \mathbf{V} (\mathbf{V} \cdot \Delta \mathbf{r}'). \quad (20)$$

With $\Delta \mathbf{r}' = \mathbf{D} = D \mathbf{n}'$, we have

$$\Delta \mathbf{R} = D \left[\mathbf{n}' + \frac{1}{2} V^2 (\mathbf{n}' \cdot \mathbf{n}_v) \mathbf{n}_v \right], \quad (21)$$

and, therefore,

$$|\Delta \mathbf{R}| = D \left[1' + V^2 (\mathbf{n}' \cdot \mathbf{n}_v)^2 + \dots \right]. \quad (22)$$

Let us return to the specifics of the Opera measurement. d is 730 kms. D_C and D_G will be larger than $2 \cdot 10^4$ kms for the satellite in “common-view from C and G”, but of that order. At best, only for some very special

configuration would the relative smallness of d be compensated by negligible trigonometric factors in the D terms. Because of the averaging over neutrino event(s), such special configurations lack relevance, if there were any in the first place. In fact there is none given the latitudes of M and of \mathbf{V} (see next paragraphs). Hence, we may neglect the d term, set $D_C = D_G \equiv D_M$, where M is the mid point between C and G, and choose this value to be $2 \cdot 10^4$.kms.

The orientation that the line of view of the satellite makes with the vertical of the mid point M will be within a solid cone where the generating line makes, say, 45° with the axis, the vertical at M. For different events, the line of view will bell over the place within that solid angle. So, a factor of 1.2 multiplying $2 \cdot 10^4$.kms may be justified, while at the same time replacing those satellites for simplification purposes with a stationary hypothetical “GPS station”, which would certainly not be a satellite. Because of the relative smallness of d , we can take the unit vectors \mathbf{n}'_C and \mathbf{n}'_G as \mathbf{n}'_M and $-\mathbf{n}'_M$. We thus have for the excess of time delay by light going the GPS route

$$2 \frac{DV^2}{c^3} (\mathbf{n}'_M \cdot \mathbf{n}_V)^2. \quad (23)$$

The candidate \mathbf{V} is the one in which the 2.7 degree cosmic microwave background (CBM) radiation would be viewed as isotropic. Its declination is minus 7 degrees. Its magnitude varies because of the translation of the earth around the sun. We take the value given by Smoot [11] for the speed of the sun with respect to CBM rest frame as approximate value of the direction of the speed of the earth. That value is 368 ± 2 kms per second. For the same reason of neutrino events averaging mentioned above, the right ascension of \mathbf{V} will be irrelevant, and we can take it to be zero, i.e. as origin of redefined right ascensions. Its declination is -7° . Since the latitude of M is approximately 45° , its vertical will never be anywhere near the direction of \mathbf{V} .

The unit vector in the direction of \mathbf{V} will then be taken to be

$$\mathbf{n}'_V = (0, -\cos 7^\circ, -\sin 7^\circ), \quad (24)$$

and, as the earth rotates,

$$\mathbf{n}'_M = (\cos 45^\circ \cos \phi, \cos 45^\circ \sin \phi, \sin 45^\circ). \quad (25)$$

The dominant term in $(\mathbf{n}'_V \cdot \mathbf{n}'_M)^2$ is $(\cos 7^\circ \cos 45^\circ \sin \phi)^2$, whose average is approximately 1/4.

We are thus left with an excess time of flight of light on CSG of $(1/2)(D/c)(V/c)^2$, which, for the given values of D and V yields $50ns$. If we replace D with $1.2D$ because of the argument made that the vertical is an average for directions but not for distances, we get $60ns$. Of course, we could have chosen 1.1 or 1.3 instead of 1.2 . The delay would then be $55ns$ or $65ns$. The coincidence is extraordinary; the theoretical argument, not too solid yet.

It would readily occur to readers the question of what about the Pioneer probes anomalies. Though, one can never be sure of having done the correct analysis in virgin territory, our analysis shows that, if there is an effect, it is much smaller than the anomaly.

8 Concluding remarks

With regards to the rationale for five dimensions, consider the following. The theory of connections is a theory of moving frames and only moving frames, whether it is presented that way or not. For an easy to understand example, let us mention that particles are left out in Cartan's theory of connections, which is the paradigm of local differential geometry: they do not enter the equations of structure. If proptime (τ) is viewed as a fifth dimension, the dual of its differential, the 4-vector-velocity, is represented as having a projection on but not as been contained in the spacetime subspace. Though not the most interesting implication of five dimensions, particles will thus enter the equations of structure through the "4-velocity" viewed as tangent vector dual to proper time.

It will be claimed in the next paper, that $U(1) \times SU(2)$ is to the $x\tau$ subspace what the Lorentz group is to tx . Here, by Lorentz group, we mean the actual group of the Lorentz transformations, or to the group of the para-Lorentzian transformations which is a non-linear representation of the Lorentz group [12], [13]. But, if $U(1) \times SU(2)$ is directly related to the tangent bundle, should $SU(3)$ not also be so? Schmeikal [14]-[15] has shown that $SU(3)$ also can be related to the tangent bundle, fermion density functions being represented by primitive idempotents in the Clifford algebra of spacetime. In the present author's opinion, the primitive idempotents should not be those of the tangent bundle but of the Kähler algebra of differential forms. A publication on this subject will see the light when the motivation will be there.

Consider next the equivalence principle. The 4-velocity \mathbf{u} is now a vector

spanning the fifth dimension but not orthogonal to spacetime. Its projection on it has naturally components $\gamma(1, u^i)$. In PL, on the other hand, its projection is $\gamma, 0, 0, 0$. In other words it is orthogonal to the 3-space subspace as in SR. We still have an equivalence principle which favors PL over SC. In our analysis [5], the $x\tau$ subspace is relativistic if spacetime (tx) is PL, and it is non-relativistic if tx is, as in *SR*.

Finally, consider the role we assigned to distances in Σ for the analysis of the Opera result. It will emerge that gravitation has to do with universal time and universal distances. The other interactions will be concerned with proptime and their 3-space rest frame. Electrodynamics has double life, represented by $U(1)$ when (electromagnetic spinorial) structures are concerned, and invariant under the Lorentz group when particles in external fields are concerned.

To conclude, the thesis presented in the combination of this and the following paper —thesis to which Opera lends a hand— is that the world looks relativistic after all. However, given the exceptions, even if presently very few, it is more accurate to say that SR is the **facade** of a more complex theory which can only be seen through cracks in the facade. If the thesis advanced in this paper happens to be correct, SR and relativistic quantum mechanics will continue to be taught —and not simply as an approximation like Newtonian mechanics is— but in the context of a very subtle, more complex reality.

9 Acknowledgements

Relevant conversations with Professors Zbigniew Oziewicz and Timir Datta, and Doctors Bernd Schmeikal and Stanley Alterman are acknowledged.

References

- [1] The OPERA collaboration, T. Adam et al. *Measurement of the neutrino velocity with the OPERA detector in the CNGS beam*. arxiv.org/pdf/1109.4897
- [2] Reichenbach, H.: *The Philosophy of Space and Time*. Dover, New York (1958).

- [3] Bohm, D.: The Special Theory of Relativity Benjamin, New York (1965)
- [4] Cattaneo, C.: Sui postulati comuni alla cinematica classica e alla cinematica relativistica, Lincei - Rend. Sc. fis. mat e nat **XXIV**, 526-532 (1958).
- [5] Vargas, J.G.: $U(1) \times SU(2)$ from the Tangent Bundle. Soon to be submitted.
- [6] Roberston, H.P.: Postulate *versus* Observation in the Special Theory of Relativity. Rev. Mod. Phys. **21** (3), 378-382 (1949).
- [7] Einstein, A.: Zur elektrodynamik bewegter Körper, Annalen der Physik, **17**, 891-921 (1905).
- [8] Thirring, W.: A Course in Mathematical Physics: Classical Field Theory, Springer-Verlag, Heidelberg (1979).
- [9] Vargas, J.G.: Revised Robertson Test Theory of Special Relativity: Space-Time Structure and Dynamics, **16** (11), 1089-1126 (1986).
- [10] Maciel, A.K.A., Tiomno, J.: Experiments to Detect Possible Weak Violations of Special Relativity, Phys. Rev. Lett. **55** (2), 143-146 (1985).
- [11] Smoot, G. F : Nobel Lecture: Cosmic background radiation anisotropies: Their discovery and ulilization. Rev. Mod. Phys. **79**, 1349-1379 (2007).
- [12] Rembielinski, J.: The Relativistic Ether Hypothesis, Physics Letters **78A** (1)33-36 (1980)
- [13] Vargas, J.G.: Revised Robertson Test Theory of Special Relativity: Supergroups and Superspace, **16** (12), 1231-1261 (1986).
- [14] Schmeikal, B.: Transposition in Clifford Algebra: $SU(3)$ from Reorientation Invariance. In: Ablamowicz, R.(ed.), Conference Proceedings on Clifford Algebras and Their Applications in Mathematical Physics, Cookeville, 2002. Birkhäuser, Boston (2003).
- [15] Schmeikal, B.: Spacetime Fermion Manifolds, in: Reimer, A. (ed.) Horizons in World Physics, Volume 271, NOVA Science Publishers, New York, N. Y. 2011, p. 319-327.

Opera's neutrinos and the Robertson test theory of the Lorentz transformations*

Jose G. Vargas[†]

Abstract

The difference in light's travel time from CERN to GPS to Gran Sasso, on the one hand, and light going the direct route in vacuum (mimicked by neutrinos), on the other hand, is analyzed with a modified Robertson test theory of the Lorentz transformations. The modification consists simply in removing the restriction of what Robertson referred to as agreement to equate the to and from speeds of light. For reasons that will be presented in a paper to soon follow, we restrict ourselves, within the new freedom, to the case of preferred frame kinematics with absolute simultaneity.

At the level of not assuming any concomitant dynamical changes in this alternative, the analysis yields *zero effect*, i.e. no change with respect to special relativity (to be expected). The 60 ns would thus remain unexplained. However, a gravitation related effect that would likely accompany an alternative kinematics yields that value up to uncertainties due to the need to simplify the experimental set up for analysis. The effect amounts to $(\lambda/2)(D/c)(V/c)^2$, where D is distance to GPS, V is speed with respect to the frame of isotropy of the cosmic background radiation and λ is a factor greater than 1, but likely not greater than 1.2 or 1.3, that reflects lack of precise knowledge of the average distance to the common view GPS satellite. A λ factor of 1.2 yields 60 ns.

*To Dr. Douglas G. Torr, supporter and collaborator of several decades.

[†]PST Associates. 138 Promontory Rd., Columbia, SC 29209. USA

1 Introduction

In their analysis [1], the Opera group assumed the constancy of the one-way speed of light, assumption shared by the physics community at large. But most physicists and philosophers interested in the foundations of SR assert that synchronizations and the one-way speed of light are matters of convention covered under the umbrella of Reichenbach's thesis of conventionality of synchronizations [2]. Consistently with this, they maintain that certain transformations alternative to the ones by Lorentz, like the para-Lorentzian transformations that we shall later consider, do not actually represent a new physics. High energy physicists, to name only the most obvious case, would find such a statement difficult to digest (This author was caught in the defense of his Ph. D. dissertation between a conventionalist and a high energy physicist; yes, I published and got my degree!). Those observations and my little anecdote are meant to ask for patience by skeptic readers, since the issue is a very subtle one. See in this respect Chapter 8 of Bohm's book on the special theory of relativity [3]

Central to our discussion will be the realization that the present version of the principle of equivalence is by itself enough to imply the Lorentz transformations (LTs) without any such conventions [4] and, therefore, imply a constant one-way speed that is not conventional (See in [4] references to previous related works, starting as early as in 1910). There is no way out of this under present interpretations of the relativity principle.

If the one-way speed of light were a matter of convention, the implications of the now famous 60 *ns* should not be a cause for concern. A convention (a definition for Einstein; an agreement for H. P. Robertson) cannot have foundation-shaking consequences. How would neutrinos know what convention was used to determine when they should arrive in Gran Sasso? However, there is some sense in which one could speak of convention, though it is dangerous to do so. I shall explain by advancing the contents of section 5.

If light traveled with a direction dependent speed different from c from CERN to GPS satellites and from there to Gran Sasso, so would the speed of light in a straight tunnel (vacuum having been made in it) between CERN and Gran Sasso. Under present understanding that we do not reject, neutrinos would also travel with a speed slightly smaller but virtually equal to the speed of light in vacuum. That speed would thus be, like light's under the thesis of this paper, direction dependent. So, this measurement amounts in principle to sending light between two places through direct and indirect

routes. Any changes in the arrival time of light from CERN to Gran Sasso via GPS would be compensated exactly by the change in the arrival time of light going the direct route in a straight tunnel. On the basis of results like this, some may find it justifiable to make the assumption of equality of the to and fro speeds since there is no way to tell the difference if it were not so.

We shall consider an alternative with preferred frame that we shall call para-Lorentzian (PL), an alternative that, either nameless or under a different name, has been invoked by different researchers for various purposes. It would be premature to give here acknowledgements, mainly because of the lengthy and negative comments that would also have to be made in more than one case. Future Opera-like experiments will tell whether the subject is worth revisiting and assign credits, or discredits for that matter.

The key part of this paper is sections 5 to 7. In section 5, we perform a para-Lorentzian analysis of the Opera experiment under the trite assumption that one should look at the kinematics only. It does not explain why neutrinos appear to show up earlier than expected.

In section 6, we imagine what gravitation could be like in a non-relativistic world that looks relativistic as per the preceding section, but where we let Newton's law be directly related to the preferred frame, rather than to the rest frame of the mass creating the gravitational field. In other words, we are speaking of a potential gravitational concomitant of a physics on the PL scenario.

In section 7, we compute the time of arrival of neutrinos in the context of that concomitant. It agrees so closely with the 60 *ns* that luck must be at work given the simplification of the experiment made to be able to perform the analysis with available data and resources.

The rationale behind the contents of sections 6 and 7 will not be easily understood without a paper which should soon follow [5]. It was written a year ago as an outgrowth of a talk given a year ago at Bauman University in Moscow. It makes the case for proptime as a fifth dimension. The argument is based on superseding the foundations of present day differential geometry. A new perspective emerges on issues such as the equivalence principle. In section 8, the last one, we shall give a preview of the implications of the 5-D scenario presented in that preprint [5]. Just to provide some limited perspective for the present paper, let us just say the following. The LTs might be the facade of a more complex reality consistent with absolute simultaneity and containing a preferred frame in its fold; physics will continue to look relativistic and one will continue to study it even if the physics presented

in this paper were correct and accepted. But there may be the occasional exception under uncommon circumstances, Opera possibly being a case in point.

We complete the description of the contents of the paper. In section 2, we show contradiction between a statement by Einstein about the one-way speed of light and what his first postulate for SR implies. This contradiction could not have been noted at the time. In section 3, we revise the Robertson test theory of the Lorentz transformations [6] by removing from it the equality of the two and fro speeds of light. In section 4, we deal with the PL transformations. All that is necessary, or at least very relevant, for the sections that then follow, whose contents has already been presented in this introduction.

2 Einstein on the one-way speed of light

The opinion of Einstein on the one-way speed of light is retrospectively relevant if we assume that it is not a constant, but that the two-way speed is. If, for whatever reason, we set the one-way speed to be equal to the two-way speed, the constancy of the latter implies the constancy of the former. In this regard, Einstein in 1905 incurred in a contradiction that could not be ascertained at the time, and that he felt might be possible: “... We assume that this definition of synchronism is free from contradictions ...” [7]

The contradiction is stated using this and the next two paragraphs. Einstein postulated the equivalence of all the inertial frames in spacetime. It was not realized at the time that this suffices to obtain the LTs up to the value of a constant, if negative ([4], and references therein). This implies that the square root of the negative inverse of that constant is an invariant with dimension of velocity. This invariant is the only speed which remains constant under those transformations. The one-way speed of light is not then a matter of conventions, but to be determined by experiment. The only reasonable option for that constant is the speed of light. The only way out of this consequence of invariant one-way speed would consist in not assuming the equivalence of all the inertial frames in the usual sense, the only sense presently available.

The issue of synchronizations and of the constant speed of light are intertwined. In paragraphs preceding immediately the aforementioned citation, Einstein had stated: “We have not defined a common “time” for A and B, for

the latter cannot be defined at all unless we establish *by definition* that the “time” required by light to travel from A to B equals the “time” it requires to travel from B to A ...” Markings and emphasis are as in the original. We wish to call attention to the “*by definition*”.

Einstein defines times t_A , t_B and t'_A instrumental in stating the equality of the two and for speeds of light as follows: “In accordance with definition the two clocks synchronize if $t_B - t_A = t'_A - t_B$ ”. A definition is a convention. We cannot make Planck’s constant be whatever we want it to be as a matter of definition. But Einstein did that with the one-way speed of light, even though his postulate of equivalence implied that it is not a matter of definition. End of explanation of contradiction.

Up to this point in this paper, the one way of speed of light has emerged as being a direct consequence of a *convention* [2], a *theorem* [4], and a *definition* [7]. The issue then becomes what does the available experimental evidence say about all this. Robertson wrote a most significance paper about it titled “Postulate *versus* observation in the Special Theory of Relativity” (emphasis in original). In the process of understanding its essence, we shall again find the characterization of the one-way speed of light. We need to understand the essence of that paper.

3 Revision of Robertson’s test theory of the Lorentz transformations

Robertson postulated [6]

(a) the existence of “a reference frame Σ —Einstein’s “rest system”—in which light is propagated rectilinearly and isotropically in free space with constant speed c ” (Emphasis in original).

He assumed for his purpose

(b) that we may “... confine ourselves to the consideration of events E in a space-time neighborhood of a given event E_0 which is so small that we may linearize T ,...” T is the general transformation that constitutes his starting point.

He then went to

(c) “... *adopt the procedure* proposed by Einstein for setting clocks which are carried by observers R at various points x^a in the reference frame S ” (emphasis added). Robertson had previously introduced S as Einstein’s

moving system.

In connection with synchronizing clocks at a distance through reflection of a light signal and dividing by two the time of the two way trip, Robertson writes:

(d) “We *agree* to set the auxiliary clock ... in such a way that it records the time t_0 for the event E of reflection”.

Further down the text, he goes on to say

(e) “... Einstein’s synchronization insures *as a matter of definition* the equality of the forward and backward velocity along any given line in S , ...” Emphasis in original.

He interprets the null result of the Michelson-Morley (MM) experiment as meaning:

(f) “*The total time required by light to traverse in free space, a distance l and to return is independent of direction*”. Emphasis in original.

He proceeds similarly with the experiment of Kennedy-Thorndike (KT):

(g) “*The total time required by light to traverse a closed path in S is independent of the velocity v of S with respect to Σ* ”. Emphasis in original.

And finally, for the Ives-Stilwell experiment (IS):

(h) “*The frequency of a moving atomic source is altered by the factor $(1 - u^2/c^2)^{1/2}$, where u is the velocity of the source with respect to the observer.*” Emphasis in original.

In that way, Robertson reaches the standard metric of special relativity. As is well known, it is left invariant by translations, LTs, spatial rotations and products of those.

If one gives a value to the one way speed of light in the path from CERN (C) to GPS (S) to Gran Sasso (G), one should ignore (c), (d) and (e) and treat Opera as a fourth experiment —though highly imperfect because of its many complications— for a the revised Robertson test theory of the LTs. To be precise, the analysis will induce us into some back engineering that it takes us beyond the testing of the LTs. We are led into whether we can consider an alternative to the LTs in a purely kinematical context. Under a plausible concomitant change in Newton’s law at the level of one part in 10^6 for the earth, Opera’s non-null result might be a way in which nature might be voicing lack of conformity with (c).

In discussing the transformations that we are about to consider in the next section, Thirring [8] stated “... it would be possible to save the notion of absolute simultaneity, but no one is willing to make the necessary *sacrifices any more*: philosophical principles are not as persuasive as *mathematical*

elegance” (emphasis added).

To the key terms *convention*, *theorem* and *definition* we add the also key terms *adoption of a procedure*, *agreement*, *sacrifices any more*, and *mathematical elegance*.

In the present paper, the one-way speed of light is a theorem if one assumes the only version of the equivalence principle that appears to be possible in a pure spacetime context. In the remainder of this paper, we shall present a new context that will be further developed in the announced sequence [5], more concerned with mathematical elegance.

4 Para-Lorentzian transformations

The revision of the Robertson test theory is better performed in terms of coordinate transformations, provided they represent changes of frames and not just simply changes of markers (See paragraph of Eq. (6)).

Of all the members of the family of transformations that comply with (f), (g) and (h) but not (e), we are now choosing the specific member where time is absolute. This is not only for esthetic or simplicity reasons, but because PL is the only member of the family chosen by our theoretical considerations on the arena of physics [5]. These transformations have been considered by a few others in the past but not worth mentioning at this point because negative comments should also accompany what may otherwise be potentially important contributions. But, if these transformations prove their worth, that work should be revisited.

Let \mathbf{V} be the velocity of the laboratory system with respect to $\Sigma(T, X, Y, Z)$. Its components can be chosen to be $(v, 0, 0)$ with respect to some appropriately oriented axes for $S'(t', x', y', z')$. With the Robertson approach but with the specified change, one can easily show how to mathematically represent a hypothetical non-compliance of nature with any one or several of (e), (f), (g) and (h) [9]. The family of “transformations” that replaces the LTs if (d) is not satisfied is

$$x' = \gamma \cdot (X - VT), \quad y' = Y, \quad z' = Z, \quad t' = hX + (\gamma^{-1} - hV)T, \quad (1)$$

where h is a family of functions of V . These transformations contain both the LTs and the PL transformations, the last ones being

$$x' = \gamma \cdot (X - VT), \quad y' = Y, \quad z' = Z, \quad t' = \gamma^{-1}T. \quad (2)$$

We define unprimed low case quantities by

$$x = x', \quad y = y', \quad z = z', \quad t = t' - Vx' \quad (3)$$

and use (3) in (2). We thus identify $S(t, x, y, z)$ as a relativistic frame with the same velocity as the PL frame S' since

$$x = \gamma \cdot (X - VT), \quad y = Y, \quad z = Z, \quad t = \gamma(T - Vx). \quad (4)$$

For arbitrary direction of the velocity, the relation between S and S' ,

$$\mathbf{r} = \mathbf{r}', \quad t = t' - (\mathbf{V} \cdot \mathbf{r}), \quad (5)$$

allows us to compute more easily than resorting directly to Σ .

All these coordinate transformations are to be viewed not as changes of markers but as representative of changes of frames. In affine space, the equation

$$x^\mu \mathbf{e}_\mu = x'^\mu \mathbf{e}'_\mu, \quad (6)$$

expresses that the translation vector can be expressed in terms of just any vector basis. A change of coordinates thus induces a change of basis and vice versa. But alternative coordinates can also be viewed simply as different sets of markers. This comment also applies to changes between Lorentz frames and frames for kinematics that do not comply with any one or several of (d), (e), (g) and (e). Hence, there is nothing special about (5) in this specific regards; one could do something totally similar for any kinematics that does not satisfy any of Robertson's three optical experiments.

The preceding considerations have an important consequence. One is not going to find any effects in experiments where there is not some element that distinguishes a change of basis from a change of markers, as the computations would be the same in both cases; since no effect can arise from a change of markers, no effect would be found by identical computations for the change of frames, if there is not such a distinguishing element.

Returning to our computations in a PL world, let \mathbf{c} and \mathbf{c}' be the velocity of light relative to S and S' . We have

$$\mathbf{c}' = \frac{d\mathbf{r}'}{dt'} = \frac{d\mathbf{r}'}{dt} \frac{dt}{dt'} = \frac{d\mathbf{r}}{dt} \frac{dt}{dt'} = \mathbf{c}(1 - \mathbf{V} \cdot \mathbf{c}'), \quad (7)$$

where we have used (4). Since \mathbf{c} and \mathbf{c}' are colinear, their unit vectors are equal

$$\mathbf{c} = \mathbf{n} = \mathbf{n}'. \quad (8)$$

where $c' \equiv |\mathbf{c}'|$ and where we take c as unit of speed. For $V \ll 1$, we get from (7),

$$\frac{1}{c'} = 1 + \mathbf{V} \cdot \mathbf{c}' + (\mathbf{V} \cdot \mathbf{c}')^2 + \dots \quad (9)$$

We also have

$$\mathbf{c} = \frac{d\mathbf{r}}{dt'} \frac{dt'}{dt} = \mathbf{c}'(1 + \mathbf{V} \cdot \mathbf{c}), \quad (10)$$

and

$$\frac{1}{c'} = 1 + \mathbf{V} \cdot \mathbf{c} = 1 + \mathbf{V} \cdot \mathbf{n} = 1 + \mathbf{V} \cdot \mathbf{n}', \quad (11)$$

which are exact equations.

5 Para-Lorentzian analysis of the Opera measurement

We shall now proceed to present an analysis of the problem of measurement of the one way speed of light tailored-made to the Opera experiment. This is a refinement and generalization of a similar argument Bohm made in just one dimension [3].

In S' , the position vectors from C to S, from S to G and from C to G will be denoted as \mathbf{D}_C , \mathbf{D}_G and \mathbf{d} . The respective unit vectors will be named \mathbf{n}'_C , \mathbf{n}'_G and \mathbf{n}'_ν . And we shall use the symbols c'_C , c'_G and c'_ν to refer to the speed of light corresponding to those directions. Obviously

$$\mathbf{D}_C + \mathbf{D}_G - \mathbf{d} = \mathbf{0}. \quad (12)$$

We shall now show that light satisfying equations (7) to (11) take the same time to cover the closed path CSGC (using a hypothetical tunnel between C and G) as if light were travelling always at constant speed c . This time is given by

$$\frac{D_C}{c'_C} + \frac{D_G}{c'_G} + \frac{d}{c'_\nu} = 0, \quad (13)$$

where c'_ν represents the speed of light if it were going from G to C.

Using (11), expression (13) becomes

$$\frac{D_C}{c}(1 + \mathbf{V} \cdot \mathbf{n}'_C) + \frac{D_G}{c}(1 + \mathbf{V} \cdot \mathbf{n}'_G) + \frac{d}{c}(1 - \mathbf{V} \cdot \mathbf{n}'_\nu) = 0, \quad (14)$$

where we have made c explicit outside the parenthesis to make obvious that we are adding time intervals. The sum of the terms obtained from the units in the parentheses yields the time that light would take to cover the path with speed c . The other terms yield the dot product by \mathbf{V} of the left hand side of (12), and is thus null. The point of null effect has been made.

Notice that the result just obtained is exact and, therefore, independent of how large c' could become. And it is because cancellations like this are the norm rather than the exception that one should not be concerned about an underlying reality that were not relativistic; it might still appear to be so.

We proceed to develop another important observation in order to understand where we should look or not look for 60 ns in the present context. Let t and t' be the times taken by light to cover the trajectories indicated by subscripts. We have proved that

$$t'_{CSG} + t'_{GSC} = t_{CSG} + t_{GSC}, \quad (15)$$

and similarly

$$t'_{CG} + t'_{GC} = t_{CG} + t_{GC}. \quad (16)$$

Solving for t'_{GC} in (16) and substituting in (15), we get

$$t_{CG} - t'_{CG} = t_{CSG} - t'_{CSG}. \quad (17)$$

t_{CG} is the time that neutrinos take to go from C to G at the speed c , and t'_{GC} is the actual time they take as per PL.

Notice that the left hand side of equation (17) does not depend on the point S. Hence neither can the right hand side even if each of its two terms does.

To conclude, if PL had to do only with the dependence of the speed of light with direction, it could not account for the effect. Many would be saying: I told you so. But there is far more to spacetime related structure in PL than just the speed of light. See, for instance, Maciel and Tiomno in connection with the concept of (practical) rigidity in SR and PL [10]. And *if there were more*, a law of nature would determine when neutrinos should arrive in Gran Sasso, not some convention that neutrinos do not know of.

6 Newton's law in preferred frame context

As explained by Maciel and Tiomno, the rotation of a practically rigid body defines two different physical configurations depending of whether we are in a

SR world or a PL world. The role that practical rigidity plays in the analysis by Maciel and Tiomno of resonance experiments in centrifuges [10] is played by Newton’s law in the Opera experiment. In one case as in the other, it is a matter of the differences ab initio between physical configurations of an experiment which, against all appearances, is not the same in a world as in the other, say the worlds of SR and PL.

Equations (5) by themselves would seem to preclude any such difference, since Newton’s law pertains to gravitostatics, where only displacement vectors in three dimensions should matter; these are the same in SR as in PL. Nature, however, could be more subtle. We have to imagine what such a PL world might look like.

Here is the crux of the problem. Given the peculiarities of light (as per the previous section), synchronizations that take place in actual life are Einstein’s, not PL synchronizations. Consider now slow clock transport. Unless a clock is at rest in Σ , it is not moving slowly. Only if the laboratory were almost at rest in Σ would slow clock transport be a valid, approximate synchronization procedure in a *PL* world, but the reason would be that, in that frame, SR and PL physics would be practically identical. In a PL world there is an *unavoidable disconnect* between its *hypothetical relation of simultaneity* and how clocks actually behave. Because of this, SR will always be part of the physics, barring the exceptional situations that catch this “malicious nature” off guard.

Synchronizations are key to the functioning of the GPS system but, in the weak or virtually flat approximation of the preferred frame scenario, Newton’s dynamical law would take its standard form in the frame Σ , not in the frame S' . That is the thesis we use here to analyze Opera. Given that Newton’s constant G and the mass of the earth are known only to one part in 10^4 , the highly precise *GPS system is an almost miraculous feat* of scientific and technological engineering. It is monitored and corrected continuously, using the more reliable system of atomic clocks on earth. Thanks to the *stability provided through that monitoring* and the self-consistency between the participant satellites that one so achieves, one can measure small distances and achieve meaningful synchronizations using the two-way speed of light.

One computes highly precise differences between the position vectors of two places without subtracting the would-be-imprecise actual distances to the center of the earth. In addition, one is dealing with distances computed with intervention of two-way speeds of light. This is not obvious because, although one-way ranging is involved in the common use of the GPS system,

the basic functioning of the system involves satellites viewed in different directions. It has the same character as two-way determinations. All this goes to say that these *computed measurements amount to corrections rather than actual values*. This is like the quantum field corrections of the hydrogen atom's fine structure. Relativistic quantum mechanics provides the bulk of the value (so to speak), but not the corrections; quantum field theory on its own cannot provide the value, only the corrections. Hence it does not matter for most purposes whether we are working with a very precise value for the mass of the earth or not.

From a PL perspective, the GPS system would be a hybrid one. The foundations of its gravitational dynamics would not be in accordance with the synchronizations that actually take place. The foundations are “preferred frame based”, *but measurements with this system (say distances in the Opera experiment) are differential* and thus based on local assumptions related to the wrong synchronizations. For each neutrino event, the distance covered by light in going from CERN to GPS satellite to Gran Sasso is determined using just one satellite, in common view from both places. It is an apparent S' distance because it is computed through the use of signals from a self-consistent system but whose orbit is then computed by “wrongly using” the underlying Newton's law. It should be based on Σ distances, not on S' distances, much less on apparent S' distances.

Consequently, we proceed to compute the effect on the time of flight of light under a presumed effect of this unavoidable mismatch. We assume that the real distance in S' is not the one actually considered to have been measured in S' (through computation on the basis of the wrong assumptions), but that it is related to it like the real Σ distance is related to the the real S' distance. Thus we shall use the relation between Σ and S' for our analysis. How could one do better than this? There are three legs to the answer: theoretical, phenomenological and practical.

From a theoretical perspective, one cannot do better without developing the beginning of a theory that covers at least a new gravitation the facade of which (loosely speaking) is Einstein's theory of gravity.

From a practical perspective, a PL-consistent GPS system would be practically unworkable. Those who designed the system already know what is practical because, as explained, they developed a very precise system going beyond the precision in the knowledge of G and of the mass of the earth.

From a phenomenological/modelling perspective, a more sophisticated analysis would have to be carried out by those who designed the system and

maintain it, but perhaps only for a case like this, where one sees the frame behind the facade. Such an effort is unwarranted at this point. Confirmation of the same anomaly by other experiments should take place first, specially since such additional experiments appear to be in the workings already.

Finally a word about something else, just in case. Inconsistencies have appeared in measurements of G at a level as high as 1 part in 10^4 . The second order effect that we are about to consider would be too small in order to explain such inconsistencies. But one might not be able to totally exclude first order effects in other situations.

7 Analysis of the Opera experiment with concomitant gravitational effect

Let us assume that we follow the course of action just outlined. We rewrite Eqs. (2) as

$$X = \gamma \cdot (x' + Vt'), \quad Y = y', \quad Z' = z', \quad T = t'. \quad (18)$$

For arbitrary direction of velocity of S' , the assignment of 3-vectors to pairs of “points” (meaning C and S, or S and G, or C and G) at constant time is given by

$$\Delta \mathbf{R} = \Delta \mathbf{r}' + \mathbf{V} \frac{\gamma - 1}{V^2} (\mathbf{V} \cdot \Delta \mathbf{r}'), \quad (19)$$

directly from the spatial part of the PL transformations, the same as for the LTs. In second order

$$\Delta \mathbf{R} = \Delta \mathbf{r}' + \frac{1}{2} \mathbf{V} (\mathbf{V} \cdot \Delta \mathbf{r}'). \quad (20)$$

With $\Delta \mathbf{r}' = \mathbf{D} = D \mathbf{n}'$, we have

$$\Delta \mathbf{R} = D \left[\mathbf{n}' + \frac{1}{2} V^2 (\mathbf{n}' \cdot \mathbf{n}_v) \mathbf{n}_v \right], \quad (21)$$

and, therefore,

$$|\Delta \mathbf{R}| = D \left[1 + V^2 (\mathbf{n}' \cdot \mathbf{n}_v)^2 + \dots \right]. \quad (22)$$

Let us return to the specifics of the Opera measurement. d is about 732 kms. D_C and D_G will be larger than 2×10^4 kms for the satellite in “common-view from C and G”, but of that order. At best, only for some very special

configuration would the relative smallness of d be compensated by negligible trigonometric factors in the D terms. Because of the averaging over neutrino event(s), such special configurations lack relevance, if there were any in the first place. In fact there is none given the latitudes of M and of \mathbf{V} (see next paragraphs). Hence, we may neglect the d term, set $D_C = D_G \equiv D_M$, where M is the mid point between C and G, and choose this value to be 2×10^4 kms.

The orientation that the line of view of the satellite makes with the vertical of the mid point M will be within a solid cone where the generating line makes, say, 45° with the axis, the vertical at M. For different events, the line of view will bell over the place within that solid angle. So, a factor of 1.2 multiplying 2×10^4 kms may be justified, while at the same time replacing those satellites for simplification purposes with a stationary hypothetical “GPS station”, which would certainly not be a satellite. Because of the relative smallness of d , we can take the unit vectors \mathbf{n}'_C and \mathbf{n}'_G as \mathbf{n}'_M and $-\mathbf{n}'_M$. We thus have for the excess of time delay by light going the GPS route

$$2 \frac{DV^2}{c^3} (\mathbf{n}'_M \cdot \mathbf{n}_V)^2. \quad (23)$$

The candidate \mathbf{V} is the one in which the 2.7 degree cosmic microwave background (CBM) radiation would be viewed as isotropic. Its magnitude varies because of the translation of the earth around the sun. We take the value given by Smoot [11] for the speed of the sun with respect to CBM rest frame as approximate value of the direction of the speed of the earth. That value is 368 ± 2 kms per second. For the same reason of neutrino events averaging mentioned above, the right ascension of \mathbf{V} will be irrelevant, and we can take it to be zero, i.e. as origin of redefined right ascensions. Its declination is -7° . Since the latitude of M is approximately 45° , its vertical will never be anywhere near the direction of \mathbf{V} .

The unit vector in the direction of \mathbf{V} will then be taken to be

$$\mathbf{n}'_V = (0, -\cos 7^\circ, -\sin 7^\circ), \quad (24)$$

and, as the earth rotates,

$$\mathbf{n}'_M = (\cos 45^\circ \cos \phi, \cos 45^\circ \sin \phi, \sin 45^\circ). \quad (25)$$

The dominant term in $(\mathbf{n}'_V \cdot \mathbf{n}'_M)^2$ is $(\cos 7^\circ \cos 45^\circ \sin \phi)^2$, whose average is approximately 1/4.

We are thus left with $(1/2)(D/c)(V/c)^2$ excess time of flight of light. This expression yields 50 *ns* for the given values of D and V . If we replace D with 1.2 D because the vertical is a reasonable average for directions, but not for distances, we get 60 *ns*. Of course, we could have chosen 1.1 or 1.3 instead of 1.2. The delay would then be 55*ns* or 65*ns*. The coincidence is extraordinary; the theoretical argument, not too solid yet.

It would readily occur to readers the question of what about the Pioneer probes anomalies. Though one can never be sure of having done the correct analysis in virgin territory, our analysis shows that, if there is an effect, it is much smaller than the anomaly.

8 Concluding remarks

With regards to the rationale for five dimensions, consider the following. The theory of connections is a theory of moving frames and only moving frames, whether it is presented that way or not. For an easy to understand example, let us mention that particles are left out of the core of Cartan's theory of connections, which is the paradigm of local differential geometry: they do not enter the equations of structure. If proptime (τ) is viewed as a fifth dimension, the dual of its differential, the 4-vector-velocity, is represented as having a projection on (but not as been contained in) the spacetime subspace. Though not the most interesting implication of five dimensions, particles will thus enter the equations of structure through the "4-velocity" viewed as tangent vector dual to proper time.

It will be claimed in the next paper, that $U(1) \times SU(2)$ is to the $x\tau$ subspace what the Lorentz group is to tx . Here, by Lorentz group, we mean the actual group of the Lorentz transformations, or to the group of the para-Lorentzian transformations (the general case does not look as the very special case considered), which is a non-linear representation of the Lorentz group [12], [13]. But, if $U(1) \times SU(2)$ is directly related to the tangent bundle, should $SU(3)$ not also be so? Schmeikal [14]-[15] has shown that $SU(3)$ also can be related to the tangent bundle, fermion density functions being represented by primitive idempotents in the Clifford algebra of spacetime. In the present author's opinion, the primitive idempotents should not be those of the tangent bundle but of the Kähler algebra of differential forms. A publication on this subject will see the light when the motivation will be there.

Consider next the equivalence principle. The 4-velocity \mathbf{u} is now a vector spanning the fifth dimension but not orthogonal to spacetime. Its projection on it has naturally components $\gamma(1, u^i)$. In PL, on the other hand, its projection is $\gamma, 0, 0, 0$. In other words it is orthogonal to the 3-space subspace as in SR. We still have an equivalence principle which favors PL over SC. In our analysis [5], the $x\tau$ subspace is relativistic if spacetime (tx) is PL, and it is non-relativistic if tx is *SR*-like.

Finally, consider the role we assigned to distances in Σ for the analysis of the Opera result. It will emerge that gravitation has to do with universal time and universal distances. The other interactions will be concerned with proper time and their 3-space rest frame. Electrodynamics has double life, represented by $U(1)$ when (electromagnetic spinorial) structures are concerned, and invariant under the Lorentz group when particles in external fields are concerned.

To conclude, the thesis presented in the combination of this and the following paper —thesis to which Opera lends a hand— is that the world looks relativistic after all. However, given the exceptions, even if presently very few, it is more accurate to say that SR is the **facade** of a more complex theory which can only be seen through cracks in the facade. If the thesis advanced in this paper happens to be correct, SR and relativistic quantum mechanics will continue to be taught —and not simply as an approximation like Newtonian mechanics is— but in the context of a very subtle, more complex reality.

9 Acknowledgements

Relevant conversations with Professors Zbigniew Oziewicz and Timir Datta, and Doctors Bernd Schmeikal and Stanley Alterman are acknowledged. Help with software from Dr. Iulian C. Bandac is appreciated.

References

- [1] The OPERA collaboration, T. Adam et al. *Measurement of the neutrino velocity with the OPERA detector in the CNGS beam*. arxiv.org/pdf/1109.4897

- [2] Reichenbach, H.: The Philosophy of Space and Time. Dover, New York (1958).
- [3] Bohm, D.: The Special Theory of Relativity Benjamin, New York (1965)
- [4] Cattaneo, C.: Sui postulati comuni alla cinematica classica e alla cinematica relativistica, Lincei - Rend. Sc. fis. mat e nat **XXIV**, 526-532 (1958).
- [5] Vargas, J.G.: $U(1) \times SU(2)$ from the Tangent Bundle. Soon to be submitted.
- [6] Robertson, H.P.: Postulate *versus* Observation in the Special Theory of Relativity. Rev. Mod. Phys. **21** (3), 378-382 (1949).
- [7] Einstein, A.: Zur elektrodynamik bewegter Körper, Annalen der Physik, **17**, 891-921 (1905).
- [8] Thirring, W.: A Course in Mathematical Physics: Classical Field Theory, Springer-Verlag, Heidelberg (1979).
- [9] Vargas, J.G.: Revised Robertson Test Theory of Special Relativity: Space-Time Structure and Dynamics, Found. Phys. **16** (11), 1089-1126 (1986).
- [10] Maciel, A.K.A., Tiomno, J.: Experiments to Detect Possible Weak Violations of Special Relativity, Phys. Rev. Lett. **55** (2), 143-146 (1985).
- [11] Smoot, G. F : Nobel Lecture: Cosmic background radiation anisotropies: Their discovery and utilization. Rev. Mod. Phys. **79**, 1349-1379 (2007).
- [12] Rembielinski, J.: The Relativistic Ether Hypothesis, Physics Letters **78A** (1)33-36 (1980)
- [13] Vargas, J.G.: Revised Robertson Test Theory of Special Relativity: Supergroups and Superspace, Found. Phys. **16** (12), 1231-1261 (1986).
- [14] Schmeikal, B.: Transposition in Clifford Algebra: $SU(3)$ from Reorientation Invariance. In: Ablamowicz, R.(ed.), Conference Proceedings on Clifford Algebras and Their Applications in Mathematical Physics, Cookeville, 2002. Birkhäuser, Boston (2003).

- [15] Schmeikal, B.: Spacetime Fermion Manifolds, in: Reimer, A. (ed.) Horizons in World Physics, Volume 271, NOVA Science Publishers, New York, N. Y. 2011, p. 319-327.